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A Plate Impact Target Design for 25.4 mm Diameter Samples Heated up to 250°C

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I. INTRODUCTION

The inert shock properties and onset/magnitude of shock reaction of many materials are known to change significantly with temperature. Quantification of these changes requires 1-D shock experiments at a range of initial temperatures. This report presents a simple plate-impact target design that allows samples of 25.4 mm or less to be tested at temperatures from ambient to 250°C.

II. TARGET DESIGN

This target was designed for use in the LANL TA-40 Chamber 9 single- and two-stage gas guns, though it is adaptable for use at other facilities. It meets the requirements of the heated shock reaction portion of the IHE Qualification Standard[1]. The usual heated target design used at Champer 9 (intended for use with 50 mm diameter by 30 mm tall samples) was judged to be overly large and cumbersome for the small sample sizes and simple diagnostics required for this experiment, so an alternative design was undertaken. An exploded diagram of the target assembly is shown in Figure 1. The main aluminum cell contains the sample and a LiF velocimetry window, 4 through holes for photonic Doppler velocimetry (PDV) or pin probes to evaluate impact tilt, and various threaded holes for assembly. To avoid the use of adhesives, which may fail or become opaque at elevated temperature, a PEEK spring is used to apply light pressure to the sample/window stack. This spring is compressed by a retaining ring that presses on a Teflon cylinder that also functions as a holder for velocimetry or pin probes. The spring and LiF window are visible before the Teflon plug is installed in Figure 2. The cavity in the main cell is large enough to allow free radial expansion of the sample, and the spring pressure is believed to be small enough to have little effect on axial expansion. This assembly is attached to a buffer plate (typically Al-6061, though other materials may be used) with countersunk screws. The buffer plate also contains the holes needed to mount the target to the gun.

A. Target Heating

The target is heated by a 104 W, fiberglass-insulated resistive heat tape from Omega (P/N FGS051-020). The heater is wrapped around the OD of the sample cell, as shown in Figure 3. The target is then insulated with This heater is usually controlled by a standard PID-based temperature controller, though a simple variable transformer and manual feedback is also sufficient. When heating, the goal is to maintain the inside surface of the sample cell 5°C above the target temperature for a 10 minute soak prior to firing. An experiment supporting this soak time will be discussed later in this report.

B. Diagnostics

The temperature of the target is monitored by thermocouples at the bottom of 4 blind holes drilled radially to within 0.5 mm of the inside surface of the sample cell. Two surface thermocouples are also placed below the heat tape on the outside surface of the sample cell.

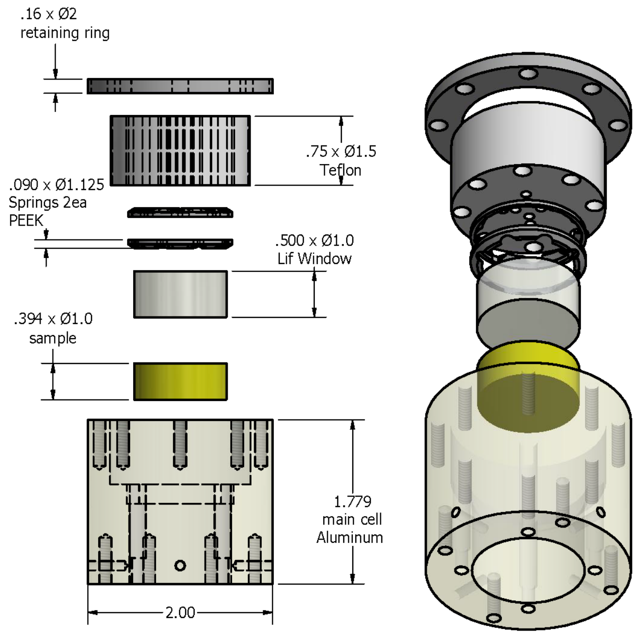

FIG. 1. An exploded schematic of the heated target presented here. The buffer plate, which would also act as the impact surface, is not shown.

FIG. 2. A partially-assembled target, attached to the buffer plate and showing the positions of the LiF window and PEEK springs.

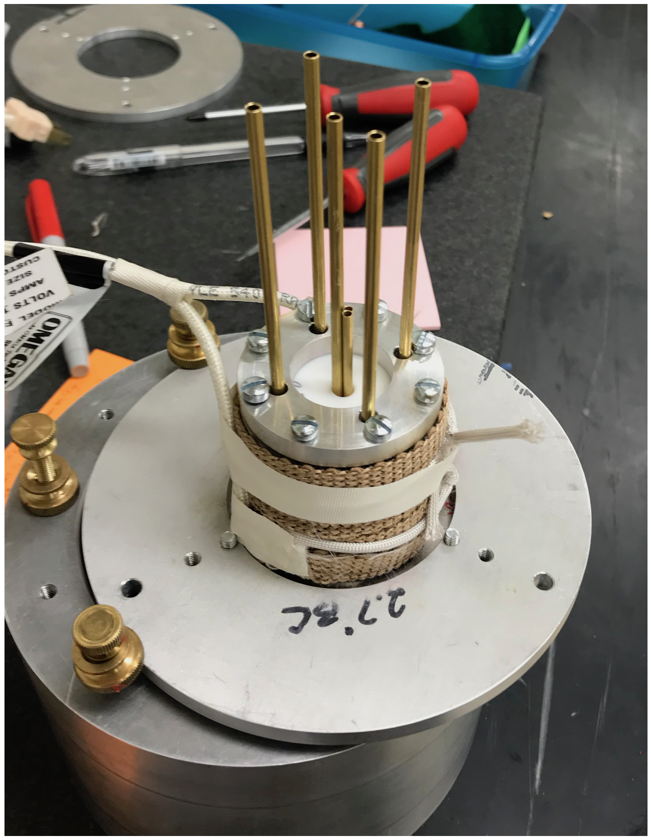

FIG. 3. Assembled target prior to application of insulation, showing the position of the heat tape and brass tubes used to align and stand off collimating PDV probes.

Tilt, impact time, and impact pressure in the buffer material is measured by 4 PDV probes located just outside the ID of the sample cell. A typical experiment uses 1-4 PDV probes to monitor the motion of the sample/LiF interface, but the Teflon plug can be machined to accept the quantity and type of probes desired for a particular experiment.

1. Special Considerations for PDV Probes and Heated Targets

Typical collimated and focusing PDV probes consist of a graded-index (GRIN) lens and a bare fiber epoxied into a brass or steel tube. These probes are typically rated by the manufacturer for use up to 80°C. Experience has shown that this style of probe will typically fail a short time after reaching 100°C. Therefore, special consideration must be given to the application of PDV probes in targets heated above 80–100°C. Keeping the probe cool is especially challenging under vacuum in the target tank of the gun, since no heat transfer can occur by convection. One option is to use a 150 mm tube to stand off the probe from the heated target. This proves to be a partial solution, with only about 50% of probes surviving a typical experiment at 250°C. Adding a 12 mm x 12 mm cylinder of brass or copper around the probe, as shown in Figure 4 provides additional thermal mass, and allows the probes to survive an approximately 45 minute heat to 250°C.

A more robust option is to use all-glass probes, which consist of bare fiber(s) embedded in a glass ferrule. These probes contain no glue, and so are expected to be more tolerant of high temperatures. Probes of this type have been placed inside the sample cell and heated to 250°C for extended periods with no failures observed. Though their collection efficiency is theoretically somewhat lower than a collimating probe, this is often an acceptable trade-off for better reliability at temperature.

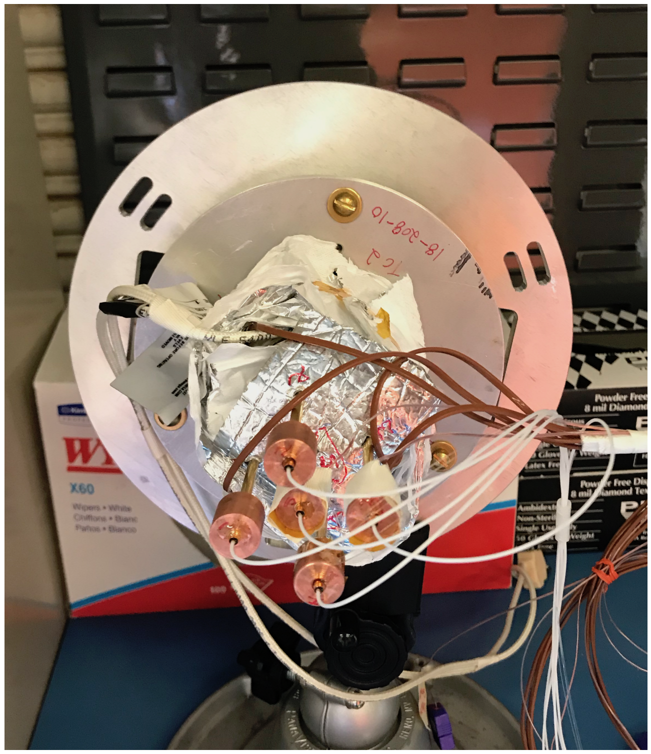

FIG. 4. An assembled target with insulation and PDV probes installed.

III. HEATING EXPERIMENT

A heating experiment was carried out to qualify this design for use in the gun, and to determine appropriate soak times to allow the sample to become approximately isothermal at the target temperature. For this experiment a ⌀25 mm x 10 mm cylinder of Viton-A was used as the sample material. In addition to the thermocouple positions described in Section II B, additional thermocouples were placed in a blind hole at the center of the sample and at the top face of the sample, below the LiF window. Temperature as a function of time in this experiment is shown in Figure 5. The desired sample temperature in this experiment was 200°C. The PID temperature controller was set to 205°C and used to control the temperature of the ID of the sample cell. Under these conditions, the central axis of the sample is approximately isothermal 7 minutes after the ID of the sample cell reaches the target temperature. Therefore, for materials with similar thermal properties to Viton-A ($k = 0.2Wm^{-1}K^{-1}$), and similar physical dimensions, a 10 minute soak is recommended.

IV. CONCLUSIONS

A new target design for performing heated 1-D shock experiments on ⌀25 mm samples is presented, and qualified by a test heat of an inert HE surrogate (Viton-A). This target is found to be suitable for tests satisfying the 'heated shock reaction' portion of the IHE Qualification Standard[1]. Special consideration is given to the application of standard velocimetry probes due to their maximum operating temperature of 80°C. A successful method to apply

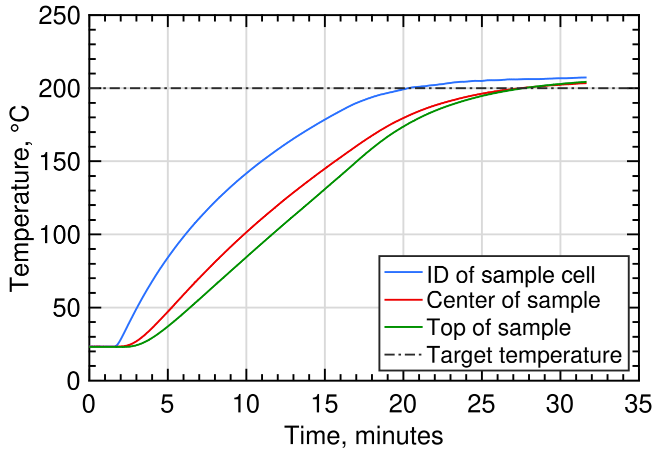

FIG. 5. Heating curve showing temperatures at the ID of the sample cell, center, and top of the sample.

these probes to tests up to 250°C is presented, as is an all-glass probe inherently capable of operation at high temperatures. This target design is now in use at the LANL Chamber 9 gas gun facility, and may be easily adapted to other facilities. The maximum temperature of this target is currently limited by the PEEK spring and Teflon plug; higher temperatures could be reached by replacing these with metallic components.

V. REFERENCES

[1]J. L. Maienschein, L. D. Leininger, and D. Hooks, "Ihe material and ihe subassembly qualification test description and criteria," Tech. Rep. LA-UP-15-29238, LLNL-TR-679331, Los Alamos National Laboratory and Lawrence Livermore National Laboratory, 2016.